NOVEL WIEN BRIDGE OSCILLATOR DESIGN USING FUNCTIONAL BLOCK STRUCTURE WITH CURRENT CONVEYORS

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Abstract. *The purpose of this paper is to generally present possibilities of the current conveyor use in the well-known active electronic circuits. Current conveyors are able to substitute all known active elements. This claim is supported by the fact, that four basic functional block structures can be realized by use of current conveyors - voltage-controlled voltage source, voltage-controlled current source, current-controlled current source and current-controlled voltage source. The paper presents particular example of use of functional block structure with current conveyors in Wien bridge oscillator, where it successfully substitutes operational amplifier on the place of active element. Both theoretical formulae and design description are given. Finally, OrCAD PSpice simulation results are presented.*

Keywords

Current conveyor, functional block structure, voltage-controlled voltage source, Wien bridge oscillator.

1. Introduction

Currently, current conveyor is already well-known active element. The first generation current conveyor (CCI) was introduced in 1968 [1]. However, the electronic industry did not require wider expansion of more current conveyor variations and their wider application in commercially produced electronic circuits and devices.

Second generation current conveyor (CCII) has received the greatest attention of the three existing current conveyor generations ever [2], particularly non-inverting positive second generation current conveyor (CCII+). It also remains the only available current conveyor variation, not counting the universal current conveyor (UCC) [3].

The number of advantages of this active element dominates over disadvantages. Positive properties of current conveyor include low voltage supply, wide frequency range, improved noise immunity, improved circuit dynamics and especially easy integrability of the resulting circuit structures using these elements. The last point comes from the fact that the principle and internal structure of current conveyor are relatively simple. Therefore the design of many modern active elements is based on the current conveyor internal structure and directly or indirectly derived from it. Let us mention for example current feedback amplifier (CFA), whose concept is based right on the current conveyor structure [4].

The paper tries to theoretically verify the versatility of block structures with current conveyors and their application in electronic circuits on place of standard applied active elements.

2. Principle and Variations of Current Conveyors

General three-port and four-port current conveyor belong to best-known and most used current conveyors (especially in theory). Three-port current conveyor can be found even in real form. Some circuit structures of sophisticated integrated circuits include variation of current conveyor CCII+ as a part of complex circuit. CCII+ input and output terminals are terminated in a limited number of these integrated circuits, so current conveyor block can be practically used.

The four-port current conveyor can be currently implemented only using the UCC [3]. However, UCC is still not yet commercially available and it is not sure, if ever UCC will be produced commercially in the future. Schematic symbol of general three-port current conveyor is shown in Fig. 1, schematic symbol of general four-port current conveyor is shown in Fig. 2.

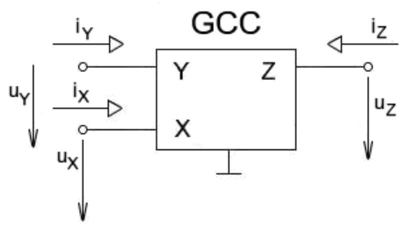

Fig. 1: Schematic symbol of general three-port current conveyor.

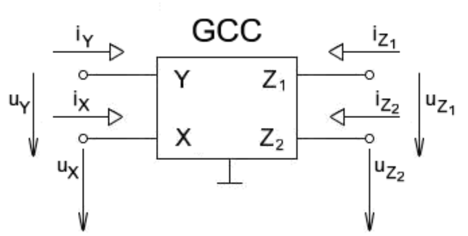

Fig. 2: Schematic symbol of general four-port current conveyor.

The terminals labeled X represent current inputs, terminals Y are voltage inputs. The terminals Z represent current outputs with positive or negative transfer of current from the terminal X [5]. In the case of the general current conveyor, voltage is also conveyed from the terminal Y to the terminal X. Selected current conveyor generations (specifically CCI and CCII) moreover convey current from the terminal X to the terminal Y [4]. These relations can be simply expressed by equations:

$$K_{U_{YX}} = \frac{u_X}{u_Y},\ K_{I_{XY}} = \frac{i_Y}{i_X},\ K_{I_{XZ}} = \frac{i_Z}{i_X}. \tag{1}$$

These transfers are referred to the coefficients *a*, *b*, *c* in the technical literature. Specifically, $K_{UYX} = a$, $K_{IXY} =$ $= b$, $K_{IXZ} = c$.

The coefficients becomes ideally values of $a =$ $= \{-1,1\}$, $b = \{-1,0,1\}$, $c = \{-1,1\}$, but they may differ from these values in practice. The coefficients *a*, *b* and *c* figure in the current conveyor definitional equations. For general three-port current conveyor they have the form:

$$u_X = a \cdot u_Y,\ i_Y = b \cdot i_X,\ i_Z = c \cdot i_X. \tag{2}$$

Specific values of the coefficients in the equations stated above directly define the current conveyor variation according to the following rules [6]. If the coefficient $a = 1$, it is a non-inverting current conveyor. However, if coefficient *a* will take value -1, it is an inverting current conveyor.

The coefficient *b* sets generation of current conveyor. The first generation current conveyors take coefficient value $b = 1$. The second generation current conveyor is defined by coefficient value $b = 0$. The third generation current conveyors take the coefficient value $b = -1$.

The coefficient *c* determines, if it will be a positive or a negative current conveyor. If the coefficient value *c* equals 1, it is a positive current conveyor. On the other hand, when $c = -1$, it is a negative current conveyor.

Overview of the three-port current conveyor variations is clearly presented in Tab. 1 [6].

Tab.1: Current conveyors variations depending on the coefficients *a*, *b* and *c*.

Conveyor Type	Coefficients		
	a	***b***	***c***
CCI+	1	1	1
CCI-	1	1	-1
CCII+	1	0	1
CCII-	1	0	-1
CCIII+	1	-1	1
CCIII-	1	-1	-1
ICCI+	-1	1	1
ICCI-	-1	1	-1
ICCII+	-1	0	1
ICCII-	-1	0	-1
ICCIII+	-1	-1	1
ICCIII-	-1	-1	-1

3. Functional Block Structures with Current Conveyors

As stated above, the current conveyors can be considered as universal elements. This claim stems from the fact, that four basic active functional block structures can be implemented by using current conveyors, as described in [4]. These four basic functional block structures theoretically allow substituting the basic types of active elements in electronic circuits. This fact is supported by the idea, that all existing active elements can be basically divided into four main groups, namely:

- voltage-controlled voltage source,
- voltage-controlled current source,
- current-controlled current source,
- current-controlled voltage source.

These four groups of active elements are identical with possible functional block structures realizable using current conveyors. For this reason, current conveyors can be considered as universal elements and it is possible to implement all of these types of active elements by using current conveyors [4].

The functional block structure belonging to voltage-controlled voltage source is shown in Fig. 3. This functional block structure is able to substitute all known connections of operational amplifier, which operates as linear amplifier with final gain. The aforenamed active element is also generally classified as voltage-controlled voltage source.

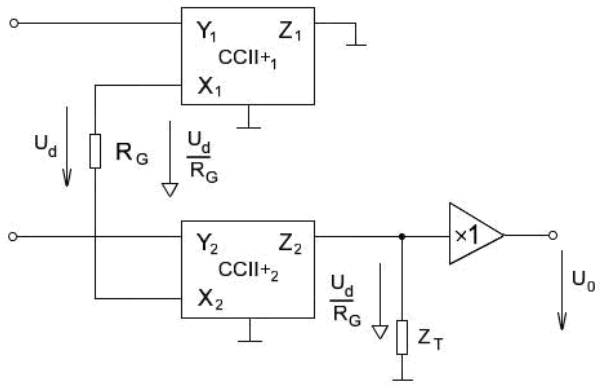

Fig. 3: Functional block structure corresponding to voltage-controlled voltage source.

The input terminals of structure Y_1 and Y_2 represent the inverting and non-inverting voltage inputs. Terminal Z_2 represents output and Z_1 have to be grounded [4]. Output signal then flows through voltage follower - a voltage amplifier with unit gain. Resistor R_G defines a total gain of functional block structure. It is evident from Eq. (3). Z_T is transimpedance, U_d is input differential voltage between inverting and non-inverting terminal and U_0 is output voltage of functional block structure [4].

$$K_U = \frac{U_0}{U_d} = \frac{Z_T}{R_G}. \tag{3}$$

The structure is constructed from CCII+, which is the only commercially available variation of current conveyor. It offers the possibility of practical realization and subsequent application in electronic circuits.

4. Proposed Wien Bridge Oscillator Using Current Conveyors

There was used well-known circuit of Wien bridge oscillator to verify the theory stated above. There was used functional block structure using two CCII+ described in the previous chapter as the active element in the circuit structure of the oscillator. The structure practically only substitutes an operational amplifier in the circuit. The resulting circuit solution is shown in Fig. 4.

Resistors R and capacitors C shown in schematic diagram make up own circuit of Wien bridge. It is known, that Wien bridge has transfer value 1/3. It is possible to define the frequency of the output signal by suitable choice of passive element R and C. Output signal frequency is defined by well-known (4). The circuit connection of resistors R_1, R_2 with an active element make up the non-inverting amplifier. The amplifier has to amplify with gain least 3 to compensate the attenuation of Wien bridge [7]. Calculation of passive element values R_1, R_2 was performed according to the basic equation:

$$f_0 = \frac{1}{2\pi RC}, \; U_2 = \left(1 + \frac{R_1}{R_2}\right) \cdot U_1. \tag{4}$$

U_2 is output voltage of and U_1 defines input voltage of the non-inverting amplifier. There was chosen the output signal frequency 1 MHz for final solution of Wien bridge oscillator using functional block structure with current conveyors. There were given the values of passive elements R_G = 1 kΩ, Z_T = 1 kΩ, R = 3,3 kΩ, C = 47 pF, R_1 = 22 kΩ and R_2 = 10 kΩ according to the equations stated above.

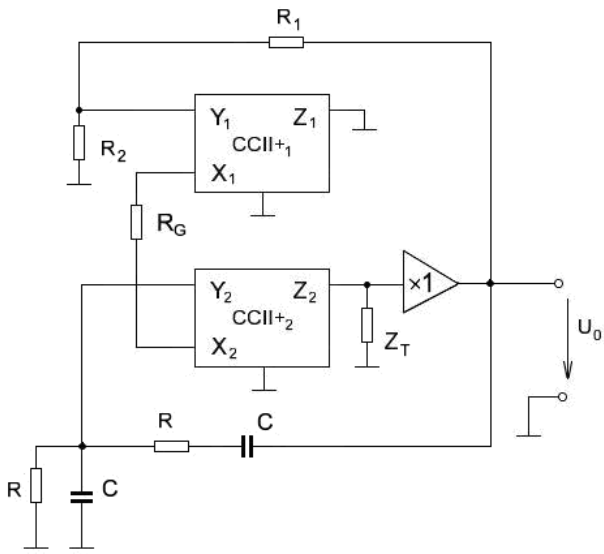

Fig. 4: Wien bridge oscillator using functional block structure with current conveyors.

OrCAD PSpice simulation was performed to verify the behavior of the resulting solution of oscillator. The final oscillator output signal response is shown in Fig. 5. There was not added the amplitude stabilizer to the complex circuit solution, therefore output signal amplitude is not stable. However, the output signal response clearly shows the emergence of oscillations that have the frequency value of 1 MHz.

5. Conclusion

The paper tries to describe basic application possibilities of current conveyors and to demonstrate their possible universal use. There was chosen one of four functional block structures representing the voltage-controlled voltage source as an example. The structure was subsequently used in the circuit of Wien bridge oscillator on place of active element, where it successfully substituted the operational amplifier.

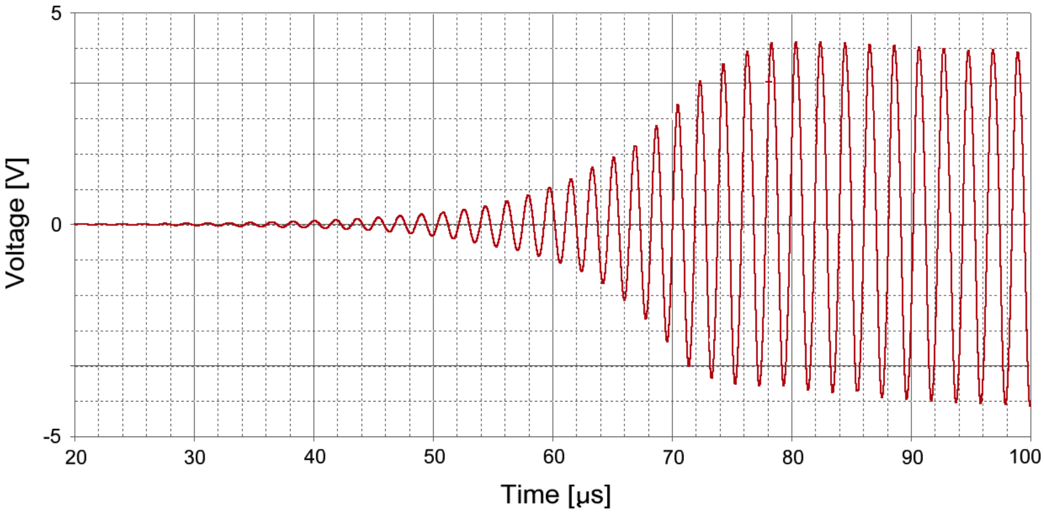

Fig. 5: Output response of Wien bridge oscillator using CCII.

The functional block structures using current conveyors bring many advantages. One of the many is the fact, that the resulting circuits can be used at higher frequencies. In our case, there was demonstratively chosen frequency value of 1 MHz. Another advantage is the low voltage supply of current conveyors. On the other hand, low commercial availability belongs to disadvantages of current conveyors. However, there can be realized a number of interesting circuit solutions using only CCII+, because four basic active functional block structure can be assembled. Therefore, this variation of current conveyor variation can be considered as universal.

Acknowledgements

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Pavel BRANDSTETTER was born in Ostrava, Czech Republic, 1955. He received the M.Sc. and Ph.D. degrees in Electrical Engineering from Brno University of Technology, Czech Republic, in 1979 and 1987, respectively. He is currently full professor in Electrical Machines, Apparatus and Drives and vice dean of Faculty of Electrical Engineering and Computer Science at VSB-Technical University of Ostrava. His current research interests are applied electronics, power semiconductor systems, microcomputer control systems and modern control methods of electrical drives.

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